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ABSTRACT

Noting that many American children enter elementary school without a critical foundation of informal mathematical knowledge, this study examined the impact of a prekindergarten mathematics curriculum grounded in research on early mathematical cognition. A project-developed instrument, the Child Math Assessment, was used on a pre-post basis to examine the informal mathematical knowledge of children. Participating in the study were 83 children enrolled in five preschool classrooms serving middle-income families. The intervention group of 41 children received the preschool mathematics curriculum and were assessed at the beginning and end of their prekindergarten year. The comparison group of 42 children did not receive the curriculum and were similarly assessed. The curriculum was delivered by means of teacher-guided small group activities, a mathematics learning center, and computer activities. Curricular units were: (1) enumeration and number sense; (2) arithmetic reasoning; (3) spatial sense; (4) geometric reasoning; (5) pattern sense and unit construction; (6) logical reasoning; and (7) nonstandard measurement. The results revealed that children in the intervention group possessed a variety of informal mathematical skills and abilities at the beginning of the prekindergarten year, but many of these abilities were not highly developed. By the end of the year, the mathematical knowledge of children in the intervention group had developed significantly, and was more extensive than the knowledge of children in the comparison group. (Author/KB)

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Enhancing Pre-kindergarten Children's Readiness for School Mathematics

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ABSTRACT

Many American children enter elementary school without a critical foundation of informal mathematical knowledge. In order to enhance the development of mathematical knowledge in young children, we developed and implemented a pre-kindergarten math curriculum that was grounded in research on early mathematical cognition. We also developed a Child Math Assessment to assess broadly children's informal mathematical knowledge. The Intervention Group of children who received the preschool math curriculum was assessed at the beginning (pretest) and end (posttest) of their pre-kindergarten year. Additionally, a Comparison Group of children who did not receive the curriculum was assessed at the end of their pre-kindergarten year. It was found that Intervention children possessed a variety of informal mathematical skills and abilities at the beginning of the pre-kindergarten year, but many of these abilities were not highly developed. By the end of the year, the mathematical knowledge of Intervention children had developed significantly, and was more extensive than the knowledge of Comparison children.

INTRODUCTION

The first national educational goal, readiness to learn, recognizes the need for young children to be better prepared for school. One aspect of readiness is the necessity for young children to construct a critical foundation of informal mathematical knowledge that will enable them to acquire formal school mathematics.

Research indicates that many young children in the United States are not receiving a broad base of support for mathematical development at home or in the preschool classroom (Klein & Starkey, 1995; Graham et al., 1997). Thus, they enter kindergarten without a sufficient foundation of informal mathematical knowledge. This research suggests that there is a need for a conceptually broad pre-kindergarten mathematics curriculum to enhance children's informal mathematical development and their readiness to learn school mathematics. Our project addresses this need through two objectives.

OBJECTIVE 1: Conduct a comprehensive study of pre-kindergarten children's informal mathematical knowledge across a range of math concepts.

OBJECTIVE 2: Implement a pre-kindergarten mathematics curriculum in preschool classrooms and determine its effectiveness at enhancing children's mathematical knowledge.

METHOD

Subjects
Pre-kindergarten children enrolled in 5 preschool classrooms serving middle-income families participated in the study. *

Intervention Group: n = 41
Mean age (Spring 1998): 5 years, 0 months

Comparison Group: n = 42
Mean age (Spring 1997): 4 years, 11 months

*We are currently continuing the study in 5 preschool classrooms serving low-income families.

Design
A **pretest-posttest design** was employed to determine the effectiveness of the curricular intervention at enhancing pre-kindergarten children's mathematical knowledge. Additionally, a Comparison Group who did not receive the curriculum was compared to the Intervention Group.

- The **Intervention Group** of children received the preschool math curriculum in their classrooms during the 1997-1998 school year.
- Their informal mathematical knowledge was assessed by pretest (Fall 1997) and posttest (Spring 1998) administrations of the Child Math Assessment (CMA).

- The **Comparison Group** was selected from the same preschool teachers' classrooms in the year preceding the intervention.
- They were tested on the CMA in the Spring (1997) of their pre-kindergarten year.

Intervention

- The intervention consisted of a pre-kindergarten math curriculum that we developed to use in preschool classrooms. Our math curriculum was designed to promote the development of a critical foundation of informal mathematical knowledge in the domains of numerical and spatial cognition.

- The curriculum was delivered to the intervention children through three instructional approaches: teacher-guided small group activities, a math learning center, and computer activities.

- The math curriculum was organized into seven topical units, each with multiple sets of math activities accompanied by concrete materials. The curriculum included the following units: (1) Enumeration and Number Sense, (2) Arithmetic Reasoning, (3) Spatial Sense, (4) Geometric Reasoning, (5) Pattern Sense and Unit Construction, (6) Logical Reasoning and (7) Non-standard Measurement.

Assessment Instrument

- The Child Math Assessment (CMA) was developed to measure preschool children's informal mathematical knowledge across a broad range of concepts.

- Tasks comprising the CMA were informed by the research literature on young children's mathematical development.

- Tasks assessed number and arithmetic knowledge as well as spatial and geometric knowledge, and encompassed a range of difficulty.

Child Math Assessment Tasks

Number and Arithmetic Tasks

- Counting Concrete Objects (small sets: 3, 7; large sets: 15, 30)
- Number Series Knowledge (N+1 and N+2 problems)
- Knowledge of Ordinal Number Terms (identify 1st through 4th ordinal position)
- One-set Addition and Subtraction: Objects Present (word problems with concrete objects)
- One-set Addition and Subtraction: Objects Absent (word problems without concrete objects)
- Two-set Addition with Hidden Sets (problems with initial sets equal or unequal)

Spatial and Geometric Tasks

- Knowledge of Shape Names (circle, square, triangle, rectangle)
- Pattern Duplication (linear color patterns with concrete objects)
- Pattern Extension (linear color patterns with concrete objects)
- Geometric Reasoning: Triangle Transformations (matching sides of congruent triangles under slide, rotation, and flip transformations)
- Serial Ordering (ordering 5 dolls by height and inserting a 6th doll into the series)

RESULTS

What is the nature of children's informal mathematical knowledge across a broad range of math concepts at the beginning of the pre-kindergarten year?

The **pretest** performance of the **Intervention Group** on the CMA was coded from videotape and scored for accuracy. Mean percent correct on the Number/Arithmetic tasks and the Spatial/Geometric tasks are presented in Tables 1 and 2.

- The results revealed a profile of strengths and weaknesses in both the numerical and spatial domains of children's informal mathematical knowledge.

- On the Number/Arithmetic tasks, children were very successful in counting small sets, understanding the ordinal terms first and second, and solving two-set addition problems with equal sets. Nevertheless, they were markedly less successful in counting large sets, understanding the ordinal number terms third and fourth, and solving two-set addition problems with unequal sets.

- On the Spatial/Geometric tasks, children were successful in naming several simple geometric shapes, duplicating patterns, and reasoning about triangle transformations. In contrast, children exhibited great difficulty in extending patterns and ordering a series of six objects.

Does providing a systematic mathematics curriculum during the pre-kindergarten year enhance preschool children's informal mathematical knowledge?

The **posttest** performance of the **Intervention Group** on the CMA was coded from videotape and scored for accuracy. Composite scores were derived by calculating the percent correct responses for all test items on the Number/Arithmetic tasks and the Spatial/Geometric tasks.

- Mean proportion correct over all tasks at the pretest and posttest is displayed in Figure 1. One-way repeated measures **ANOVAs** on the two sets of composite scores indicated that children's accuracy increased significantly on both the Number/Arithmetic tasks ($p < .001$) and the Spatial/Geometric tasks ($p < .001$). Additional t-test comparisons showed that children's accuracy was significantly greater on Spatial/Geometric tasks than on Number/Arithmetic tasks at both the pretest ($p < .005$) and posttest ($p < .001$).

- Mean percent correct on the Number/Arithmetic tasks and the Spatial/Geometric tasks are presented in Tables 3 and 4. T-test comparisons of children's pretest and posttest performance revealed a striking finding: Accuracy increased significantly from pretest to posttest on all tasks but one (number series knowledge of N+2 problems). Moreover, the majority of comparisons were significant at the .001 level.

Does the informal mathematical knowledge of the Intervention children at the end of the pre-kindergarten year differ from that of the Comparison children who did not receive the math curriculum?

The performance of the **Comparison Group** on the CMA at the end of their pre-kindergarten year was coded from videotape and scored for accuracy. Composite scores were derived for the Number/Arithmetic tasks and the Spatial/Geometric tasks as described above. In the following analyses, the Spring 1998 (posttest) performance of the **Intervention Group** was compared with the Spring 1997 performance of the **Comparison Group**.

- Mean proportion correct by the Intervention Group and the Comparison Group is displayed in Figure 2. One-way **ANOVAs** on the two sets of composite scores found that Intervention children were more accurate than Comparison children on both the Number/Arithmetic tasks ($p < .05$) and Spatial/Geometric tasks ($p < .001$).

- T-tests comparing the Intervention Group with the Comparison Group on individual tasks revealed a more differentiated pattern of results. Intervention children demonstrated significantly greater accuracy on all the Spatial/Geometric tasks. However, on the Number/ Arithmetic tasks, they exceeded the accuracy of the Comparison children only on the two-set addition task.

CONCLUSIONS

- Our study provides new information about informal mathematical knowledge in preschool children from middle-income families. The findings indicate that although children possess some numerical and spatial abilities at the beginning of their pre-kindergarten year, there are also striking weaknesses in their mathematical knowledge. Several skills and abilities that are present at this age have undergone little development.

- When preschool children were provided with a pre-kindergarten math curriculum, however, their informal mathematical knowledge in both the numerical and spatial domains was enhanced. We conclude that a conceptually broad pre-kindergarten math curriculum can support preschool children's mathematical development and provide the critical foundation needed to be ready to learn a standards-based math curriculum in elementary school.

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Table 1

Mean Percent Correct on Number and Arithmetic Tasks Intervention Group – Pretest

Standard Counting	
Small Sets	Large Sets
81	18

Ordinal Number Terms			
First	Second	Third	Fourth
76	63	27	20

One-Set Addition & Subtraction Objects Present
48

One-Set Addition & Subtraction Objects Absent
26

Two-Set Addition	
Initial Sets: Equal	Unequal
63	44

Number Series Knowledge	
N+1	N+2
67	29

Table 2

Mean Percent Correct on Spatial and Geometric Tasks Intervention Group - Pretest

Knowledge of Shape Names

Circle	Square	Triangle	Rectangle
85	78	80	44

Pattern Duplication	Pattern Extension
68	19

Geometric Reasoning: Triangle Transformations	Serial Ordering
61	43

Table 3

Mean Percent Correct on Number and Arithmetic Tasks Intervention Group – Posttest

Standard Counting	
Small Sets	Large Sets
95	50

Ordinal Number Terms			
First	Second	Third	Fourth
88	82	50	58

One-Set Addition & Subtraction Objects Present
72

One-Set Addition & Subtraction Objects Absent
48

Two-Set Addition	
Initial Sets: Equal	Unequal
93	80

Number Series Knowledge	
N+1	N+2
85	34

Table 4

Mean Percent Correct on Spatial and Geometric Tasks
Intervention Group - Posttest

Knowledge of Shape Names

Circle	Square	Triangle	Rectangle
98	95	95	85

Pattern Duplication	Pattern Extension
97	45

Geometric Reasoning: Triangle Transformations	Serial Ordering
91	83

Figure 1

Mean Proportion Correct on Number/Arithmetic Tasks and Spatial/Geometric Tasks: Intervention Group Pre-test vs. Post-test

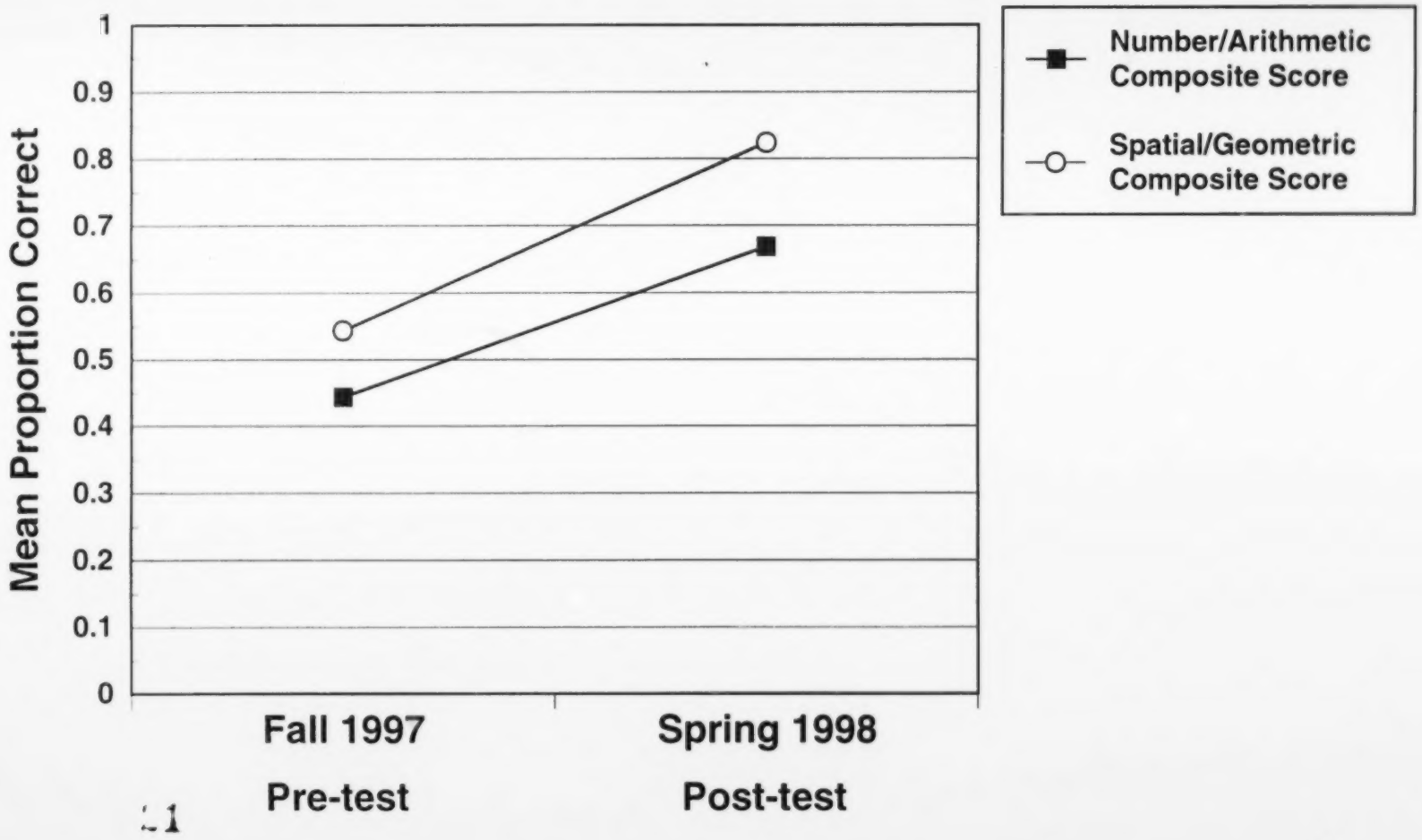

Figure 2

Mean Proportion Correct on Number/Arithmetic Tasks and Spatial/Geometric Tasks: Intervention Group vs. Comparison Group